Optical pick-up device

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Inventor:	AKIRA KIMURA [JP]; KOHEI OTA [JP]
Applicant:	KONISHIROKU PHOTO IND [JP]
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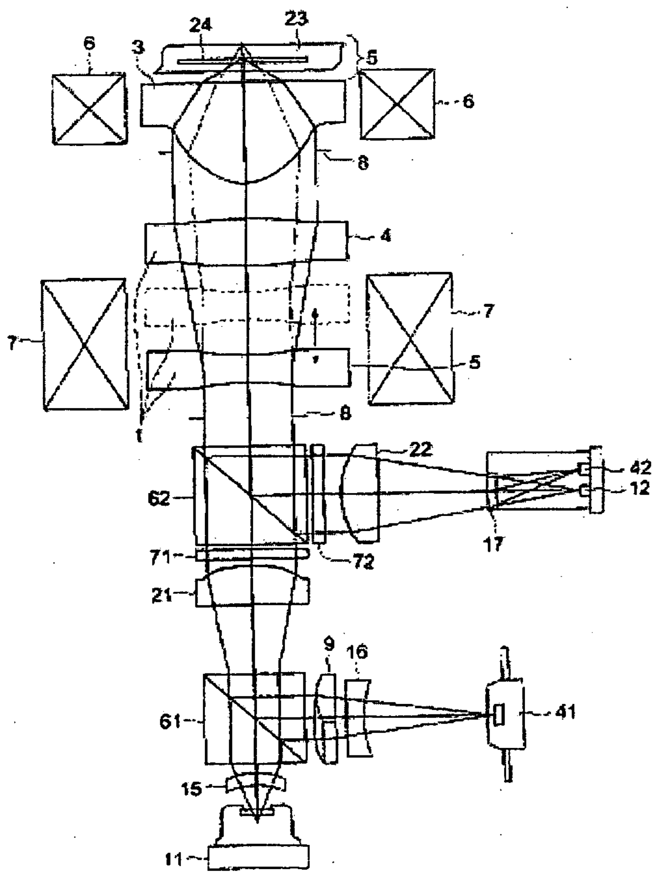
An optical pickup apparatus for conducting recording and/or reproducing information of an optical information recording medium, comprises a light source (11); a converging optical system having an objective lens (3); and a photo-detector. The converging optical system comprises a plastic lens (3) and a spherical aberration deviation correcting element (4,5) to correct deviation of a spherical aberration of the converging optical system. A numerical aperture of the objective lens at an image-side is 0.65 or more.

FIG. 1



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[71]申请人 柯尼卡株式会社

地址 日本东京都

[72]发明人 木村徹 大田耕平

[74]专利代理机构 中国国际贸易促进委员会专利商标事务所

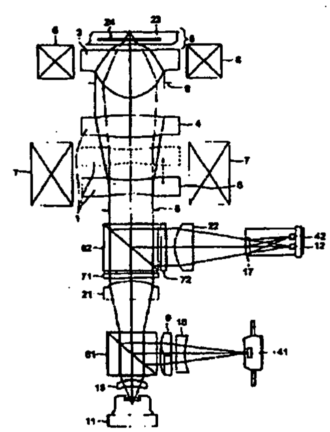
代理人 马 浩

权利要求书7页 说明书142页 附图页数48页

[54]发明名称 光学拾取装置

[57]摘要

一种用于进行记录和/或再现光信息记录介质上信息的光学拾取装置，包括 一光源；一具有物镜的聚光光学系统；以及一光电检测器。该聚光光学系统包括 一个塑料透镜和一个球面像差偏差矫正元件，以矫正该聚光光学系统的球面像差 的偏差。该物镜象方的数值孔径是0.65或更大。



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权利要求书

1. 一种用于进行记录和/或再现光信息记录介质上信息的光学拾取装置，包括：

一光源；

一聚光光学系统，其将光源发射的光通量会聚到光信息记录介质的信息记录面上，以便再现和/或记录光信息记录介质上的信息，该聚光光学系统具有物镜；以及

一光电检测器，其从信息记录面接收反射的光通量；

其中，该聚光光学系统包括至少一个塑料透镜和一个球面像差偏差矫正元件以矫正聚光光学系统的球面像差的偏差，该物镜象方的数值孔径是 0.65 或更大。

2. 根据权利要求 1 的光学拾取装置，其中球面像差偏差矫正元件包括可沿光轴方向移动的可移动元件。

3. 根据权利要求 2 的光学拾取装置，其中聚光光学系统包括一耦合透镜。该耦合透镜包括至少一个用作球面像差偏差矫正元件的可移动元件的透镜组。

4. 根据权利要求 3 的光学拾取装置，其中光源发出的光通量波长为 500nm 或更短，该耦合透镜至少有一具有环形衍射结构的衍射面，具有衍射面的透镜是塑料透镜。可移动元件是塑料透镜。物镜是塑料透镜。

5. 根据权利要求 3 的光学拾取装置，其中聚光光学系统包括耦合透镜组，该耦合透镜具有至少两个透镜组，并且两个透镜组中至少一个透镜组用作球面像差偏差矫正元件的可移动元件。

6. 根据权利要求 3 的光学拾取装置，其中聚光光学系统包括耦合透镜。该耦合透镜由一个透镜组构成，该透镜组用作球面像差偏差矫正元件的可移动元件。

7. 根据权利要求 6 的光学拾取装置，其中满足下面的公式：

$0.05 \leq |m| \leq 0.5 \quad (m<0)$

其中 m 表示该物镜和耦合透镜的组合光学系统的放大率。

8. 根据权利要求 2 的光学拾取装置，其中聚光光学系统包括一耦合透镜，并且聚光光学系统还在该耦合透镜与物镜之间包括一具有至少一个正透镜的正透

说 明 书

光学拾取装置

本发明涉及一种光学拾取装置，一种记录/再现光信息记录介质上信息的设备和扩束器，尤其涉及一种光学拾取装置、物镜和扩束器，通过它们能在高密度光信息记录介质上有效地矫正球面像差的变化。

近来，根据短波长红色半导体激光的实际应用，开发出高密度光盘 DVD（数字多用盘），其尺寸几乎与传统光盘相同，即光信息记录介质 CD（致密盘），其容量被显著增大，在不远的将来，预示在市场上还会出现更高密度的下一代光盘。在用这种光盘作为媒体的光信息记录和再现设备的光学系统中，为了得到记录信号的高致密或者为了再现高密度记录信号，要求减小通过物镜将光会聚到记录媒体上的光斑直径。为了满足这种要求，实际状况是考虑减小作为光源的激光的波长或增大物镜的 NA。

在这种关系中，当减小激光波长或增大物镜的 NA 得以实现时，即使在由将相当长波长激光和低 NA 的物镜组合构成的光学拾取装置中的几乎微不足道的问题也进一步出现了，其中通过所述光学拾取装置在传统光盘例如 CD 或 DVD 上进行信息的记录和再现。

在同时缩短激光波长和增大物镜的 NA 时出现的问题是由于温度和湿度改变使光学系统的球面像差变化。即，与玻璃透镜相比，通常在光学拾取装置使用的塑料透镜由于温度和湿度变化容易变形，从而折射率改变。即使由于折射率的改变而使球面像差变化在用于传统拾取设备中的光学系统中不是问题，其量在减小激光波长和增大物镜 NA 的组合中也是不可忽略的，并且产生了光斑直径增大的问题。因此，在采用塑料透镜的光学系统中，球面像差变成了重要的问题。

另外，在缩短激光波长和增大物镜的 NA 的组合中的另一个问题是出现在物镜上的球面像差由于光源波长的轻微偏差而偏差。在用半导体激光器作为光学拾取装置中的光源时，在半导体激光器的实际产品之间存在 ± 10nm 的偏差。所以，如果用波长偏离参考波长的半导体激光器作为光源，由于数值孔径变大，出现在物镜上的球面像差也变大。因此，如果确定用具有偏离参考波长的波长的半导体激光器作为光源，就需要对要用作光源的半导体激光器进行选择。结果，增加了

半导体激光器的成本。

另外，在缩短激光波长和增大物镜 NA 的组合中的另一个问题是光学系统的球面像差由于光盘保护层（透明基板）的厚度误差而出现偏差。由于保护层厚度误差引起的球面像差与物镜的数值孔径的四次方成正比出现。因此保护层厚度误差的影响随着物镜数值孔径变大而变大，这会导致不能稳定地进行记录或再现信息。

在这种关系中，为了信息的记录或再现，在要求减小激光波长和增大物镜的 NA 的下一代光盘和传统光盘之间，光源的波长和物镜的 NA 如上面所描述的那样彼此非常不同。而且，为了抑制在下一代光盘中预示的由于盘面从垂直于光轴的表面倾斜而产生的彗差，减小透明基板的厚度是有效的，但是，根据那样，透明基板厚度与传统光盘例如 CD 显著不同。例如，提出在下一代中使用的光盘包括厚度为 0.1mm 的透明基板，这个厚度与 CD 或 DVD 的透明基板的厚度显著不同。所以，如果 CD 或 DVD 的信息通过在下一代中使用的物镜再现，可以产生大球面像差。因此，至少通过利用普通物镜，不显著增加成本，以及通过致密光学拾取设备，如何通过抑制包括下一代光盘的不同光学信息记录媒体的球面像差记录或再现信息是一个问题。

此外，另一个问题是由于激光光源波长的微小变化在物镜中引起轴向色差。由于使用短波长，则因一般光学透镜材料对波长的微小变化而引起的反射率变化更大。因此，由于波长的微小变化导致的焦点的散焦量变大。但是事实上可见，物镜的焦深由 $k \cdot \lambda / NA^2$（k 是比例常数，λ 是波长，NA 是物镜象方的数值孔径）表达，故使用的光源的波长越短，焦深越小，甚至不允许少量的散焦量。因此，在用短波长光源例如蓝紫半导体激光器（约 400nm 波长）和具有高象方数值孔径的物镜的光学系统中，为了防止由于半导体激光的模式跳变现象引起波长变化，或者由于高频叠加引起波阵面像差变坏，轴向色差的矫正变得非常重要。

本发明是针对上述现有技术中的问题作出的，本发明的目的在于提供一种聚光光学系统和一种以简单结构能有效矫正光学拾取装置中每个光学表面由于激光光源波长变化、温度和湿度变化以及光信息记录介质上的透明基板（基板）的厚度误差而产生的球面像差中的偏差的光学拾取装置，尤其能将塑料透镜用于聚光光学系统。

此外，本发明的另一个目的是提供一种光学拾取装置及其物镜和扩束器，

通过该光学拾取装置能有效地矫正由于半导体激光器模式跳变和 HFCS（高频叠加）引起的轴向色差。

另外，本发明的再一个目的是提供一种光学拾取装置，该光学拾取装置配有短波长激光器和高 NA 物镜。而且它能记录或再现不同光信息记录介质的信息。下文中，将举例说明解决上述问题的本发明装置。

（A） 一种用于进行记录和/或再现光信息记录介质上信息的光学拾取装置，包括:

一光源;

一聚光光学系统，其将光源发射的光通量会聚到光信息记录介质的信息记录面上，以便再现和/或记录光信息记录介质上的信息，该聚光光学系统具有物镜；以及

一光电检测器，其从信息记录面接收反射的光通量;

其中，该聚光光学系统包括至少一个塑料透镜和一个球面像差偏差矫正元件以矫正聚光光学系统的球面像差的偏差，该物镜象方的数值孔径是 0.65 或更大。

（B）一种光信息记录介质的记录和/或再现装置，用于记录和/或再现光信息记录介质上的信息，包括:

一光学拾取装置，其包括:

一光源;

一聚光光学系统，以将光源发射的光通量会聚到光信息记录介质的信息记录面上，以便再现和/或记录光信息记录介质上的信息，该聚光光学系统具有物镜；以及

一光电检测器，以接收从信息记录面反射的光通量;

其中，该聚光光学系统包括至少一个塑料透镜和一个球面像差偏差矫正元件以矫正聚光光学系统的球面像差的偏差，而且象方物镜的数值孔径是 0.65 或更大。

（C）一种在光信息记录介质的记录和/或再现装置中使用的球面像差偏差矫正元件，包括:

具有至少一个正透镜的正透镜组；以及

具有至少一个负透镜的负透镜组，

度在5%至90%之间的环境变化来说，由于为了矫正由物镜形状和折射率中至少其中一个因素变化和由光源（振动）波长变化引起的球面像差的变化而在光源和物镜之间设置一个装置，故即使当物镜中折射率发生变化时或者即使当光源波长发生变化时，相应于使用光学拾取装置的环境的温度或湿度变化，因此能有效抑制由它们造成的物镜的球面像差的变化。

在这种关系中，将物镜限定为包括‘在光源和物镜之间’，因此，在本发明中，甚至设在物镜表面上的衍射面也能变成一个矫正球面像差变化的装置。

（2）一种光学拾取装置，包括：波长为λ的光源，聚光光学系统，所述聚光光学系统包括通过光信息记录介质的透明基板将光源发射的光通量会聚到信息记录面上的物镜、和从光信息记录介质接收反射光的光检测器，其中在光源和物镜之间设置一矫正球面像差变化的装置，并且因为用于矫正球面像差变化的该装置能将球面像差矫正到例如 0.2λrms 至小于 0.07λrms，故能有效地抑制由于在使用光学拾取装置的环境中由温度和湿度变化和/或光源波长的微小变化引起的物镜球面像差变化。

（3）当矫正球面像差变化的装置能将球面像差矫正到 0.5λrms 至不超过 0.07λrms 时，（2）中描述的光学拾取装置是优选的。

（4）一种光学拾取装置，包括光源，聚光光学系统，所述聚光光学系统包括通过光信息记录介质的透明基板将光源发射的光通量会聚到信息记录面上的物镜、和从光信息记录介质接收反射光的光检测器，其中因为在光源和物镜之间设置一个用于矫正物镜中产生的球面像差变化的装置，例如能有效地抑制由于使用光学拾取装置的环境中的温度或湿度变化和光源波长的微小变化引起的物镜球面像差的变化。

（5）因为在半导体激光器波长方面各个体之间存在约±10nm的偏差，故在使用具有短波长的光源和高象方数值孔径的物镜的光学系统中，当使用偏离参考波长的半导体激光时，它变成该装置性能退化的一个参数，并且是选择半导体激光器所必需的。（5）中描述的光学拾取装置是一种光学拾取装置，它包括光源、聚光光学系统，所述聚光光学系统包括通过光信息记录介质的透明基板将光源发射的光通量会聚到信息记录面上的物镜、和从光信息记录介质接收反射光的光检测器，其中因为在光源和物镜之间设置一个矫正由光源波长的微小变化造成在物镜中产生球面像差变化的装置，故能有效地抑制使用偏离参考波长的半导体激光

正光源的振动波长的轻微变化、温度和湿度变化以及光信息记录介质的保护层厚度的轻微偏差中至少两个或两个以上因素组合在光学系统的每个光学表面上造成的球面像差偏差。根据激光振动波长的轻微偏差、温度和湿度变化以及光信息记录介质的保护层厚度的轻微偏差中至少两个或两个以上因素组合在光学系统上产生的球面像差的矫正，通过沿光轴方向将耦合透镜移动一个合适的量来改变进入物镜的光通量的发散角。依靠这个，能消除光学系统上造成的球面像差偏差。

此外，最好通过沿光轴方向移动耦合透镜来矫正在光学系统的每个光学表面上造成的球面像差偏差，使得在光学系统的球面像差波动到”过”侧时可以增大耦合透镜和物镜之间的距离，通过沿光轴方向移动耦合透镜使得在光学系统的球面像差波动到”欠”侧时可以减小耦合透镜和物镜之间的距离。如果沿光轴方向移动耦合透镜使得物镜和耦合透镜之间的距离被增大，与耦合透镜移动之前的情况相比，更多的发散光进入物镜。这使得能在物镜上产生欠球面像差。所以，当由于上述原因在光学系统上造成过球面像差时，如果通过将耦合透镜移动一个适当的量来增大物镜和耦合透镜之间的距离，则能刚好消除所产生的过球面像差。相反，如果沿光轴方向移动耦合透镜使得耦合透镜和物镜之间的距离被减小，与耦合透镜移动之前的情况相比，更多会聚光进入物镜。这使得能在物镜上产生过球面像差。所以，当由于上述原因产生欠球面像差时，如果通过将耦合透镜移动一个适当的量来减小物镜和耦合透镜之间的距离，则刚好能消除所产生的欠球面像差。

最好包括沿光轴方向移动耦合透镜的移动装置。在实际的光学拾取装置上，移动耦合透镜使得在光学系统上产生的球面像差可以得到合适的矫正，同时监视再现信号的 RF 信号。作为耦合透镜的移动装置，可以使用音圈型驱动器和压电驱动器。

在本说明书中使用的衍射面意味着一种结构（或表面），其中在光学元件的表面例如透镜表面上提供浮雕，向它施加作用从而通过衍射改变光线的角度。当在一个光学表面内存在产生衍射的区域或不产生衍射的区域时，它意味着产生衍射的区域。对于浮雕的形状，例如在光学元件的表面上形成一种几乎围绕光轴的同心环带的形状，已知每个环带形成锯齿型，并包括这种形状。特别是这种锯齿形环带结构最好。

在本说明书中，狭义上，假定物镜意味着布置成最靠近光信息记录介质以

差（变化）矫正元件（装置）以矫正聚光光学系统的球面像差的偏差（变化）．物镜象方的数值孔径不小于 0.65（最好不小于 0.75）．

光源最好是波长不大于 500nm 以应用于高密度光信息记录介质的半导体激光二极管．当波长是这种短波长时，最好因为本发明的效果而变得显著．

聚光光学系统最好具有耦合透镜例如准直透镜．耦合透镜可以由一个透镜或一个透镜组组成．或者包含多个透镜或多个透镜组．此外，在波阵面像差不大于 0.07λrms 的条件下，聚光光学系统最好能在光信息记录介质的预定数值孔径内将从光源发出的波长λ的光通量会聚到光信息记录介质的信息记录面上．更可取的是，聚光光学系统能在不大于 0.05λrms 的条件下会聚光通量．

物镜可以由一个透镜或一个透镜组组成．或者包含多个透镜或多个透镜组．从成本和安装准确度角度来看，物镜最好由一个透镜组成．此外，物镜最好至少有一个非球面．

本发明的光学拾取装置适用于检测来自信息记录面的反射光并再现和/或记录信息的拾取装置．

光电检测器是检测反射光的检测器，最好使用将光信号转换成电信号的元件，例如 PDIC．

设在聚光光学系统中的塑料透镜可以是物镜或耦合透镜例如准直透镜，或者组成球面像差偏差矫正元件的透镜．或者组成轴向色差矫正元件的透镜．或其他透镜．当然，在聚光光学系统中的所有透镜可以由塑料制成．

球面像差偏差（变化）矫正元件可以由一个光学元件组成．或者可以有两个以上的光学元件．

此外，作为要通过球面像差偏差（变化）矫正元件矫正的聚光光学系统的球面像差的偏差（变化）的例子，列出以下例子．

第一个例子是由于温度和/或湿度变化而造成的球面像差偏差（变化）．例如，这种偏差是由于温度−30 至+85℃、湿度 5%至 90%之间的环境改变，由光学元件（特别是由塑料形成的光学元件）的形状和折射率两个因素中至少其中一个因素改变而造成的球面像差的变化．第二个例子是由光源的波长偏差（变化）和/或光源波长的制造误差造成的球面像差偏差（变化）．在这种关系下，本文中使用的[波长偏差（变化）]意味着光学拾取装置的光源的波长由于温度、湿度或时间的改变而微小改变约−10nm 至+10nm，[波长的制造误差]意味着由于在生产光

源时每个光源偏差造成的波长误差．第三个例子是由于光信息记录介质的透明基板厚度偏差（变化）造成的球面像差的偏差（变化）．透明基板厚度的偏差（变化）包括一个光信息记录介质的透明基板厚度的轻微变化（最好小于 100μm），还包括在至少两种光信息记录介质之间透明基板的厚度差，最好指前者．第四个例子是由于聚光光学系统的光学元件例如透镜的制造误差（例如表面形状误差或光轴方向上的厚度误差）造成的球面像差偏差（变化），如果球面像差偏差矫正元件能矫正第四例的球面像差偏差，则制造精度不需要太严格，可以提高透镜生产率．

顺便提及，当温度升高时，总的来说，在折射透镜的情况下，在信息记录面上产生球面像差，而当温度下降时，产生欠矫正的球面像差．（但是，当使用有两个透镜的物镜时，当温度升高时有时产生欠矫正的球面像差）．当湿度增大时，在折射透镜的情况下在信息记录面上产生欠矫正的球面像差，而当湿度下降时，产生过矫正的球面像差．当光源的波长变长时，在折射透镜的情况下在信息记录面上产生过矫正的球面像差，而当光源的波长变短时，产生欠矫正的球面像差．此外，当光信息记录介质的透明基板厚度增大时，在折射透镜的情况下在信息记录面上产生过矫正的球面像差，而当透明基板的厚度减小时，产生欠矫正的球面像差．

此外，球面像差偏差矫正元件最好能将 0.07λrms 至 0.2λrms 的球面像差矫正到不大于 0.07λrms．更可取的是，能将 0.07λrms 至 0.5λrms 的球面像差矫正到不大于 0.07λrms．

球面像差偏差（变化）矫正元件可以具有沿光轴方向可移动的可移动元件，或者可以仅由一个固定元件组成。此外，球面像差偏差矫正元件可以是可移动元件和固定元件的组合．

下面描述球面像差偏差（变化）矫正元件具有可移动元件的模式．在具有可移动元件的情况下，当可移动元件沿光轴方向移动时，可移动元件能通过沿光轴方向移动来改变射出光通量的边缘光线的倾斜角，矫正球面像差的偏差（变化）．在这种关系下，可移动元件最好是一个透镜或一个透镜组．更可取的是，可移动元件具有塑料透镜．球面像差偏差矫正元件有固定元件和可移动元件时，固定元件也可以具有塑料透镜．此外，可移动元件在至少一个表面上有具有非球面的非球面透镜．它可以是有两个非球面的透镜．当它有固定元件和可移动元件

可应用各种模式。例如，列出使用具有可移动元件的球面像差偏差矫正元件的模式。当球面像差偏差矫正元件的可移动元件沿光轴方向移动时，改变入射到物镜的光通量的边缘光线的倾斜角，并且矫正各个信息记录面的位置产生的球面像差的偏差，以及把光通量会聚到各个信息记录面来记录和/或再现信息。

另外，在上述的说明中，当波长λ的光通量被会聚到光信息记录介质的各个信息记录面上时，优选在用于记录和/或再现光信息记录介质的信息的预定数值孔径内，信息记录面上的波阵面像差不大于 0.07λrms，并且优选不大于 0.05λrms。

而且，优选使本发明的光学拾取装置具有检测聚光光学系统引起的的球面像差的偏差的球面像差偏差矫正元件。基于这种检测装置的检测结果，在球面像差偏差矫正元件具有可移动元件时通过移动可移动元件，或在球面像差偏差矫正元件具有其在垂直于光轴方向上的折射率分布可变的装置时，通过改变折射率来矫正球面像差的偏差，

另外，本发明的为记录和/或再现光信息记录介质上信息的光信息记录介质记录和/或再现装置，具有本发明的如上所述的光学拾取装置。优选它具有主轴电机或电源。

在本实施例中使用的非球面以下面的[等式 1]表达。其中 X 是沿光轴方向的坐标轴，h 是垂直于光轴方向的坐标轴，光前进方向是正向，r 是傍轴曲率半径，k 是圆锥系数，A_{21} 是非球面系数

[等式 1]

$$X=\frac{h^2/r}{1+\sqrt{1-(1+k)h^2/r^2}}+\sum_{i=2}^{\infty}A_{2i}h^{2i}$$

在本实施例中使用的球面以[等式 2]表达，作为光程差函数。

[等式 2]

$$\phi b=\sum_{i=1}^{\infty}b_{2i}h^{2i}$$

参考附图，本发明的优选实施例描述如下。图 1 是根据本发明的光学拾取装置的主要结构图。在图 1 中，提供进行第一光信息记录介质 24 的记录和/或再现的第一光源 11 和进行第二光信息记录介质 23 的记录和/或再现的其波长不同于第一光源 11 的第二光源 12，提供转换从各个光源发射的发散光通量的发散角的耦合透镜 21 和 22、作为使从各个光源发出的光通量沿几乎相同方向前进的光

路合成装置的光束分离器 62、把来自光束分离器 62 的光通量会聚到信息记录媒体的信息记录面 5 上的物镜 3 以及从光信息记录介质接收反射光的光检测器 41 和 42。在附图中，数字 8 是光阑、数字 9 是柱面透镜。数字 71 和 72 是 1/4 波片，数字 15 是减小来自光源 11 的发散光通量的发散角的耦合透镜。数字 16 是凹面透镜。数字 17 是把反射的光通量分离开的全息图。

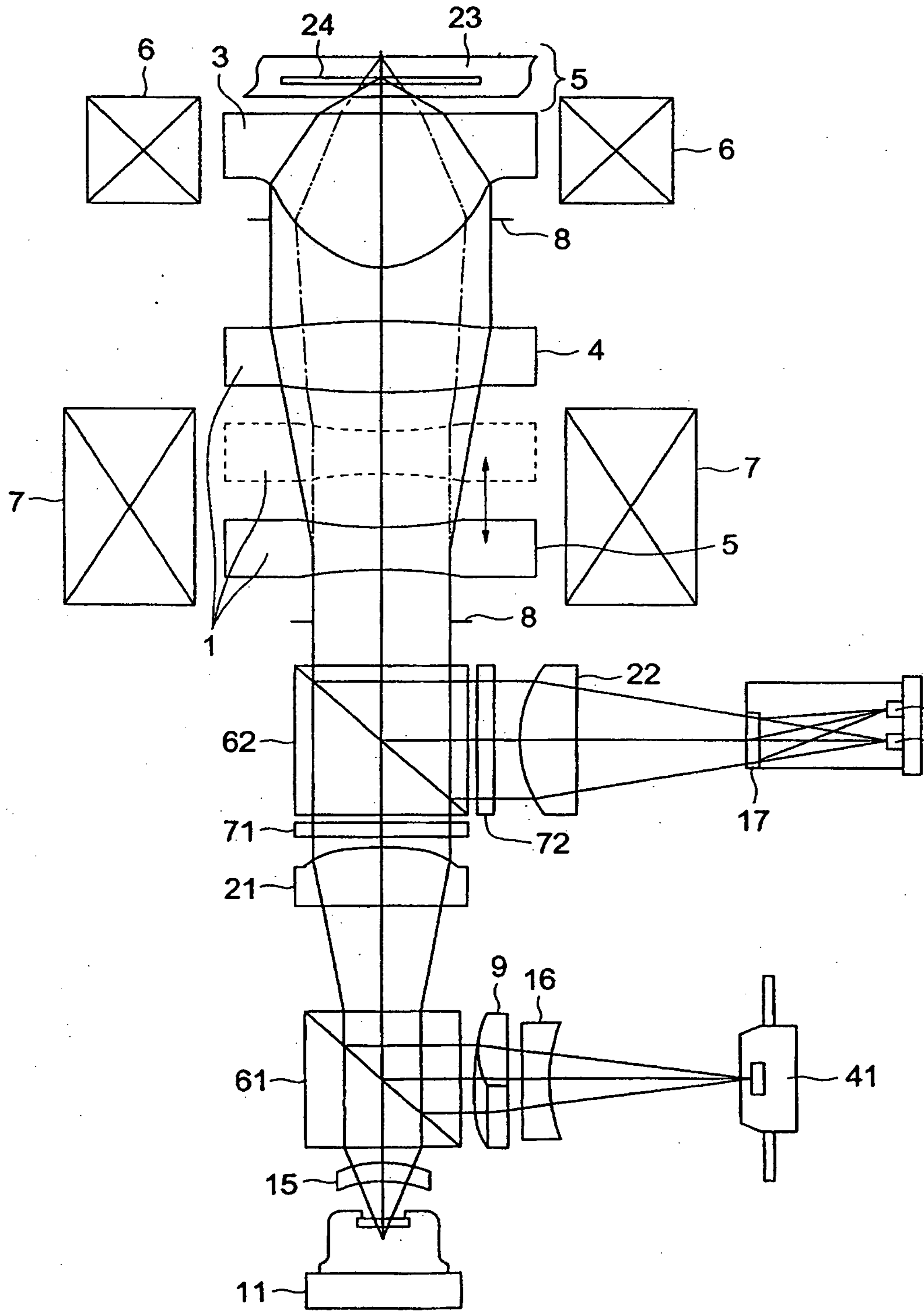
另外，在本实施例中，作为矫正物镜 3 的球面像差的变化的装置和发散角改变装置，提供从光源侧顺序设置的负透镜 5 和正透镜 4 以及致动器 7（后面这些都成为球面像差矫正装置与发散角改变装置）。致动器 7 用作传送装置，以通过沿光轴方向移作用为光学元件的负透镜 5 来改变光通量的边缘光线的倾斜角。而且，与本实施例相关的是在表示光学系统的特定部分的例子 1 到 4 中，由可传送的负透镜 5 和正透镜 4 构成的所谓的扩束器的例子有时表达为球面像差矫正装置。在这种关系中，数字 6 是沿光轴方向驱动物镜 3 来调焦的致动器。定义为第一光源 11 可发射波长 λ 1=405nm 的激光，第二光源 12 可发射波长 λ 2=655nm 的激光。

在下面描述的例子中，在例子 1、2、11、12 中，在物镜 3 上设置衍射面并矫正轴向色差，在例子 3 到 5 中，把特定材料用于负透镜 5 和正透镜 4 并矫正轴向色差，在例子 6 到 8、13 和 14 中，在负透镜 5 和正透镜 4 至少之一上设置衍射面并矫正物镜 3 的轴向色差，在例子 9 和 10 中，通过负透镜 5 和正透镜 4 的特定材料以及正透镜 4 上设置的衍射面之间的协作效应矫正物镜 3 的轴向色差。另外，例子 4,5 和 12 是利用用于不同光信息记录介质的同一光学系统进行信息的记录或再现的例子。就此而论，在物镜 3 的下面的例子中，通过利用其饱和吸水不大于 0.01%并且其对于光源波长 400nm 的光通量的内透射比是 90.5%且其对于光源波长 700nm 的光通量的穿透率是 92%的塑料材料形成。而且，在下面的例子中，在仅使用图 1 所示的本实施例的第一光源 11 的例子中，尽管忽略了特定实施例的附图，通常在图 1 的光学拾取装置中，可应用例如去除第二光源 12、耦合透镜 22、光束分离器 62、光检测器 42、1/4 波片 72 和全息图 17 的模式。各个例子如下所述。

[例子 1]

与例子 1 中负透镜 5、正透镜 4 和物镜 3 构成的光学系统相关的数据在表 1 中表示。就此而论;，在后面所示的数据中，10 的次幂（例如 $2.5\mathrm{X}10^{-3}$）用 E（例

图 1



Optical pick-up device

Description of corresponding document: **EP1154417**

BACKGROUND OF THE INVENTION

[0001] The present invention relates to an optical pick-up apparatus, an apparatus for recording/reproducing information of an optical information recording medium, and beam expander, and particularly to an optical pick-up apparatus, objective lens and beam expander, by which variations of the spherical aberration can be effectively corrected in a high density optical information recording medium.

[0002] Recently, according to the practical use of a short wavelength red semiconductor laser, the development of a DVD (digital versatile disk) which is a high density optical disk whose size is the almost same as a conventional optical disk, that is, a CD (compact disk) which is an optical information recording medium, and whose capacity is greatly increased, is advanced, and in near future, it is presupposed that a higher density next generation optical disk also appears in the market. In the optical system of the optical information recording and reproducing apparatus using such the optical disk as a medium, in order to attain the high densification of the recording signal, or to reproduce the high density recording signal, it is required that a spot diameter to converge the light onto the recording medium through the objective lens, is reduced. In order to attain this requirement, there is the actual situation that the reduction of the wavelength of the laser as the light source or the increase of the NA of the objective lens are considered.

[0003] In this connection, when the reduction of the wavelength of the laser or the increase of the NA of the objective lens thus comes to be realized, even an almost negligible problem in the optical pick-up apparatus structured by the combination of the comparatively long wavelength laser and the objective lens of low NA by which the recording or reproducing of the information is conducted on the conventional optical disk such as the CD or DVD, it is more actualized.

[0004] A problem actualized in the combination of the shortening of the wavelength of the laser and the increase of the NA of the objective lens, is a variation of the spherical aberration of the optical system due to the temperature and humidity change. That is, in comparison with a glass lens, a generally used plastic lens in the optical pick-up apparatus is easily deformable due to the temperature or humidity change, and thereby, the refractive index changes. Even in a variation of the spherical aberration by the change of the refractive index which is not a problem in the optical system used in the conventional pick-up apparatus, its amount is not negligible in the combination the reduction of the wavelength of the laser and the increase of the NA of the objective lens, and a problem in which the spot diameter is increased, is generated. Accordingly, in the optical system employing a plastic lens, a spherical aberration becomes an important problem.

[0005] Further, another problem in the combination of the shortening of the wavelength of the laser and the increase of the NA of the objective lens, is deviation of a spherical aberration taking place on the objective lens due to the slight deviation of wavelength of the light source. In the semiconductor laser used as a light source in the optical pickup apparatus, there is a deviation of +/- 10 nm among actual products of the semiconductor laser. Therefore, if a semiconductor laser having an wavelength deviating from a reference wavelength is used as the light source, the spherical aberration taking place on the objective lens becomes larger as the numerical aperture becomes lager. Owing to this, if it is determined that the semiconductor laser having an wavelength deviating from a reference wavelength is used as the light source, the selection for the semiconductor laser to be used as the light source will be required. As a result, the cost of the semiconductor laser will be raised.

[0006] Further, another problem in the combination of the shortening of the wavelength of the laser and the increase of the NA of the objective lens, is deviation of a spherical aberration of the

optical system due to errors in the thickness of a protective layer (or a transparent substrate) of the optical disk. Since the spherical aberration caused by the errors in the thickness of the protective layer occurs in proportion to fourth power of numerical aperture of the objective lens, the influence of the errors in the thickness of the protective layer becomes larger as the numerical aperture of the objective lens becomes larger, there my be a fear that recording or reproducing information can not be conducted stably.

[0007] In this connection, for the recording or reproducing of the information, between the optical disk of the next generation requiring the combination of the reduction of the wavelength of the laser and the increase of the NA of the objective lens, and the conventional optical disk, the wavelength of the light source and the NA of the objective lens are greatly different from each other as described above. Further, in order to suppress the coma greatly generated due to the tilt of the disk surface from the surface perpendicular to the optical axis which is presupposed in the optical disk of the next generation, it is effective to reduce the transparent substrate thickness, however, according to that, the transparent substrate thickness is greatly different from the conventional optical disk such as a CD. For example, an optical disk proposed for use in a next future generation comprises a transparent substrate having a thickness of 0.1 mm which is greatly different from the thickness of a transparent substrate of CD or DVD. Therefore, if the information of CD or DVD is reproduced by the objective lens for use in the next future generation, a large spherical aberration may be occurred. Accordingly, at least by using the common objective lens, without greatly increasing the cost, and by a compact optical pick-up apparatus, how to record or reproduce the information by suppressing the spherical aberration for the different optical information recording medium including the next generation optical disk, is a problem.

[0008] Further, the other problems is a problem of the axial chromatic aberration caused in the objective lens due to minute variations of the wavelength of the laser light source. The change of the reflective index due to the minute variation of the wavelength of the general optical lens material is larger as the short wavelength is used. Therefore, the defocus amount of the focal point caused due to the minute variation of the wavelength becomes large. However, as it can be seen from a fact that the depth of focus of the objective lens is expressed by k . lambda /NA<2> (k is a proportional constant, lambda is the wavelength, and NA is a numerical aperture of an image side of the objective lens), the shorter the wavelength of the used light source is, the smaller the depth of the focus is, and even a few defocus amount is not allowed. Accordingly, in an optical system using a short wavelength light source such as the blue purple semiconductor laser (about 400 nm wavelength) and an objective lens having a high image side numerical aperture, in order to prevent a wavelength variation due to the mode hop phenomenon of the semiconductor laser, or the deterioration of the wave front aberration due to the high frequency superimposition, a correction of the axial chromatic aberration becomes important.

SUMMARY OF THE INVENTION

[0009] The present invention has been made in view of the above problems in prior and an object of the present invention is to provide an converging optical system and an optical pickup apparatus capable of correcting efficiently with a simple structure deviation in a spherical aberration occurring in each optical surface in an optical pickup apparatus due to variations in wavelength of a laser light source, changes in temperature and humidity, and errors in the thickness of a transparent base plate (substrate) on an optical information recording medium and in particular, capable of using a plastic lens for the converging optical system.

[0010] Further, another object of the present invention is to provide an optical pick-up apparatus by which the axial chromatic aberration due to the mode hopping and HFCS (high frequency superimposition) of the semiconduction laser can be effectively corrected, and its objective lens and the beam expander.

[0011] Further, sill another object of the present invention is to provide an optical pick-up apparatus which is provided with the short wavelength laser and the high NA objective lens, and

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which can record or reproduce the information for the different optical information recording medium. Hereinafter, examples of means of the present invention to solve the above problems will be exemplified.

(A) An optical pickup apparatus for conducting recording and/or reproducing information of an optical information recording medium, comprises:

a light source;
a converging optical system to converge light flux emitted from the light source on an information recording plane of the optical information recording medium so as to conduct reproducing and/or recording information of the optical information recording medium, the converging optical system having an objective lens; and
a photo-detector to receive reflected light flux from the information recording plane;
wherein the converging optical system comprises at least a plastic lens and a spherical aberration deviation correcting element to correct deviation of a spherical aberration of the converging optical system and a numerical aperture of the objective lens at an image-side is 0.65 or more.

(B) An optical information recording medium recording and/or reproducing apparatus for conducting recording and/or reproducing information of an optical information recording medium, comprises:
an optical pickup apparatus comprising:

a light source;
an converging optical system to converge light flux emitted from the light source on an information recording plane of the optical information recording medium so as to conduct reproducing and/or recording information of the optical information recording medium, the converging optical system having an objective lens; and
a photo-detector to receive reflected light flux from the information recording plane;
wherein the converging optical system comprises at least a plastic lens and a spherical aberration deviation correcting element to correct deviation of a spherical aberration of the converging optical system and a numerical aperture of the objective lens at an image-side is 0.65 or more.

(C) A spherical aberration deviation correcting element for use in an optical information recording medium recording and/or reproducing apparatus, comprises:

a positive lens group having at least one positive lens; and
a negative lens group having at least one negative lens,
wherein a numerical aperture of the objective lens at an image-side is 0.65 or more,
at least one of the positive lens group and the negative lens group is movable in a direction of an optical axis and
deviation of a spherical aberration of the optical pickup apparatus is corrected by moving the at least one of the positive lens group and the negative lens group in the direction of an optical axis, and
wherein the spherical aberration deviation correcting element comprises at least one plastic lens.

(D) A spherical aberration deviation correcting element for use in an optical pickup apparatus for recording and/or reproducing information of the optical information recording medium, comprises:

a positive lens group having at least a positive lens; and
a negative lens group having at least a negative lens, wherein at least one of the positive lens group and the negative lens group is a movable element movable in a direction of an optical axis and the movable element can change the slope angle of the marginal ray of an exit light flux by moving in a direction of the optical axis, and
wherein each positive lens of the spherical aberration deviation correcting element has Abbe's numbers of 70 or less or each negative lens of the spherical aberration deviation correcting element has Abbe's numbers of 40 or more and the spherical aberration deviation correcting element comprise at least a diffractive surface having a ring-shaped diffractive structure.

(E) A spherical aberration deviation correcting element unit for use in an optical information recording medium recording and/or reproducing apparatus, comprising:

a spherical aberration deviation correcting element comprising,
a positive lens group having at least one positive lens; and
a negative lens group having at least one negative lens,
wherein at least one of the positive lens group and the negative lens group is movable in a direction of an optical axis and deviation of a spherical aberration of the optical pickup apparatus is corrected by moving the at least one of the positive lens group and the negative lens group in the direction of an optical axis, and
wherein each positive lens has Abbe's numbers of 70 or less and each negative lens has Abbe's numbers of 40 or more and the spherical aberration deviation correcting element comprise at least a diffractive surface having a ring-shaped diffractive structure; and
a moving device to at least one of the positive lens and the negative lens in a direction of an optical axis.

[0012] Further, another preferable means to attain the above object are exemplified.
(1) An optical pick-up apparatus comprises a converging optical system including a light source, and an objective lens to converge the light flux emitted from the light source onto the information recording plane (surface) through a transparent substrate of an optical information recording medium, and a light detector to light-receive the reflected light from the optical information recording medium, wherein the objective lens includes a lens composed of at least one plastic lens, and because a means for correcting a variation of the spherical aberration caused by a change of at least one of the shape and the refractive index of the objective lens, and by the variation of the (oscillation) wavelength of the light source, for the environmental change between the temperature of -30 C to + 85 C, and the humidity of 5 % to 90 %, is provided between the light source and the objective lens, even when a change of the refractive index is generated in the objective lens, or even when the change of the wavelength of the light source is generated, corresponding to the temperature or humidity change of the environment in which the optical pick-up apparatus is used, the variation of the spherical aberration of the objective lens caused due to them can be effectively suppressed.

[0013] In this connection, the objective lens is defined to be included 'between the light source and the objective lens', and accordingly, even the diffractive surface provided on the surface of the objective lens can become a means for correcting the variation of the spherical aberration in the present invention.
(2) An optical pickup apparatus comprises the light source of the wavelength lambda , a converging optical system including the objective lens to converge the light flux emitted from the light source onto the information recording plane through the transparent substrate of the optical information recording medium, and a light detector for receiving the reflected light from the optical information recording medium, wherein a means for correcting the variation of the spherical aberration is provided between the light source and the objective lens, and because the means for correcting the variation of the spherical aberration can correct the spherical aberration up to 0.2 lambda rms to less than 0.07 lambda rms, for example, the variation of the spherical aberration of the objective lens caused due to the temperature or humidity change of the environment in which the optical pick-up apparatus is used, and/or the minute variation of the wavelength of the light source, can be effectively suppressed.
(3) The optical pick-up apparatus described in (2) is preferable when the means for correcting the variation of the spherical aberration can correct the spherical aberration up to the 0.5 lambda rms to not more than 0.07 lambda rms.
(4) An optical pick-up apparatus comprises the light source, a converging optical system including the objective lens to converge the light flux emitted from the light source onto the information recording plane through the transparent substrate of the optical information recording medium, and a light detector for light-receiving the reflected light from the optical information recording medium, wherein, because a means for correcting the variation of the spherical aberration generated in the objective lens is provided between the light source and the objective lens, for example, the variation of the spherical aberration of the objective lens caused due to the

temperature or humidity change of the environment in which the optical pick-up apparatus is used, and/or the minute variation of the wavelength of the light source, can be effectively suppressed.
(5) Because there is a deviation of about +/- 10 nm among the individual bodies in the wavelength of the semiconductor laser, in the optical system using the objective lens having the light source of the short wavelength and the high image side numerical aperture, when the semiconductor laser deviated from the wavelength as the reference is used, it becomes a factor of the performance deterioration of the apparatus, and it may be necessary to select the semiconductor laser. An optical pick-up apparatus described in (5) is an optical pick-up apparatus comprising a light source, a converging optical system including the objective lens to converge the light flux emitted from the light source onto the information recording plane through the transparent substrate of the optical information recording medium, and a light detector for light-receiving the reflected light from the optical information recording medium, wherein, because a means for correcting the variation of the spherical aberration generated in the objective lens due to the minute variation of the wavelength of the light source, is provided between the light source and the objective lens, the variation of the spherical aberration of the objective lens caused when the semiconductor laser deviated from the wavelength as the reference is used, can be effectively suppressed, thereby, the selection of the semiconductor laser is not necessary.
(6) An optical pick-up apparatus comprises a light source, a converging optical system including the objective lens to converge the light flux emitted from the light source onto the information recording plane through the transparent substrate of the optical information recording medium, and a light detector for light-receiving the reflected light from the optical information recording medium, wherein, because a means for correcting the variation of the spherical aberration generated in the conversing optical system due to the temperature or humidity change is provided between the light source and the objective lens, thereby, for example, the variation of the spherical aberration of the objective lens caused due to the temperature or humidity change of the environment in which the optical pick-up apparatus is used, can be effectively suppressed.
(7) An optical pick-up apparatus comprises a light source, a converging optical system including the objective lens to converge the light flux emitted from the light source onto the information recording plane through the transparent substrate of the optical information recording medium, and a light detector for light-receiving the reflected light from the optical information recording medium, wherein, because a means for correcting the variation of the spherical aberration generated in the light conversing optical system due to the minute variation of the oscillation wavelength of the light source and the temperature or humidity change is provided between the light source and the objective lens, thereby, for example, the variation of the spherical aberration of the objective lens caused due to the temperature or humidity change of the environment in which the optical pick-up apparatus is used, and caused when the semiconductor laser deviated from the reference wavelength as the light source is used, can be effectively suppressed.
(8) The optical pick-up apparatus described in (1) to (7) is characterized in that a means for correcting the variation of the spherical aberration includes at least one positive lens and at least one negative lens, and at least one of them is a movable element which can move in the optical axis direction.
(9) Further, the optical pick-up apparatus described in (1) to (7) is characterized in that a means for correcting the variation of the spherical aberration has a positive lens group having the positive refractive power including at least one positive lens, and a negative lens group having the negative refractive power including at least one negative lens, and at least one lens group of them is a movable element which can move in the optical axis direction.

[0014] In the optical pick-up apparatus used the light source of the short wavelength, as described above, the variation of the spherical aberration due to the wavelength variation of the light source or the variation of the spherical aberration due to the temperature and humidity change is large. Particularly, when the objective lens of the high image side numerical aperture (high NA) or the objective lens composed of plastic material is used, the variation is increased. Accordingly, in the optical pick-up apparatus using the light source of the short wavelength, it is particularly necessary to provide a means for correcting the variation of these spherical aberration. When the spherical aberration of the objective lens is varied due to the minute change of the wavelength or the temperature or humidity change, by moving the movable element of a means for correcting the variation of the spherical aberration by an appropriate amount, and by changing the slope angle of the marginal ray of the light flux incident to the objective lens so that the spherical

Fig. 59 is a spherical aberration view of a coupling lens and an objective lens according to the example 22.
Fig. 60 is a sectional view of a coupling lens and an objective lens according to the example 23.
Fig. 61 is a spherical aberration view of a coupling lens and an objective lens according to the example 23.
Fig. 62 is a view showing another embodiment of an optical pickup apparatus employing the objective lens of the present invention.
Fig. 63 is a sectional view showing an embodiment employing a refracting index distribution changing element according to the present invention.
Fig. 64 is a sectional view showing another embodiment employing a refracting index distribution changing element according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0077] The optical pick-up apparatus to conduct the recording and/or reproducing of the information of the optical information recording medium of the present invention has a light source, a converging optical system having the objective lens for converging the light flux emitted from the light source onto the information recording plane of the optical information recording medium so that the reproducing and/or recording of the information of the optical information recording medium can be conducted, and a photo detector for receiving the reflected light flux from the information recording plane. The converging optical system has at least one plastic lens, and a spherical aberration deviation (variation) correcting element (means) for correcting the deviation (variation) of the spherical aberration of the converging optical system. The numerical aperture at the image side of the objective lens is not smaller than 0.65 (preferably, not smaller than 0.75).

[0078] It is preferable that the light source is a semiconductor laser diode whose wavelength is not larger than 500 nm so as to be applied for the high density optical information recording medium. When the wavelength is such the short wavelength, it is preferable because the effect of the present invention becomes conspicuous.

[0079] It is preferable that the converging optical system has a coupling lens such as a collimator lens. The coupling lens may be composed of one lens, or one lens group, or comprises plurality of lenses or plurality of lens groups. Further, it is preferable that the converging optical system can converge the light flux of the wavelength lambda emitted from the light source onto the information recording plane of the optical information recording medium within a predetermined numerical aperture of the optical information recording medium in the condition of the wavefront aberration not larger than 0.07 lambda rms. More preferably, the converging optical system can converge the light flux in the condition of not larger than 0.05 lambda rms.

[0080] The objective lens may be composed of one lens, or one lens group, or comprises plurality of lenses or plurality of lens groups. From the viewpoint of cost and the mounting accuracy, it is preferable that the objective lens is composed of a single lens. Further, it is preferable that the objective lens has at least one aspheric surface.

[0081] The optical pick-up apparatus of the present invention can be applied for a pickup apparatus to detect the reflected light from the information recording plane and reproduces and/or records the information.

[0082] The photo detector is a detector to detect the reflected light, and an element to convert optical signals into electronic signals such as PDIC is preferably used.

[0083] The plastic lens provided in the converging optical system may be an objective lens, or a coupling lens such as a collimator lens, or a lens constituting the spherical aberration deviation correcting element, or a lens constituting the axial chromatic aberration correcting element, or other lenses. Of course, all of the lenses in the converging optical system may be made of plastic.

[0084] The spherical aberration deviation (variation) correcting element may be composed of one optical element, or may have more than two optical elements.

[0085] Further, as examples of the deviation (variation) of the spherical aberration of the converging optical system to be corrected by the spherical aberration deviation (variation) correcting element, the following examples are listed.

[0086] The first example is the deviation (variation) of the spherical aberration accompanied by the change of the temperature and/or the humidity. For example, it is the variation of the spherical aberration generated accompanied by the change of at least one of the shape of the optical element (specifically, the optical element formed of plastic) and refractive index due to the environmental change between the temperature -30 to +85 DEG C, humidity 5 % to 90 %. The second example is the deviation (variation) of the spherical aberration accompanied by the wavelength deviation (variation) of the light source and/or the manufacturing error of the wavelength of the light source. In this connection, the [wavelength deviation (variation)] used herein means that the wavelength of the light source of the optical pick-up apparatus is minutely varied by about -10 nm to +10 nm accompanied by the change of the temperature, humidity or time, and the [manufacturing error of the wavelength] means the error of the wavelength due to the deviation for each of light sources at the time of the production of the light source. The third example is the deviation (variation) of the spherical aberration accompanied by the deviation (variation) of the thickness of the transparent substrate of the optical information recording medium. The deviation (variation) of a thickness of the transparent substrate includes a slight change in a thickness of the transparent substrate (less than 100 mu m preferably) of one optical information recording medium, and it also includes a difference of a thickness of a transparent substrate between at least two kinds of optical information recording medium, and the former is preferably meant. The fourth example is the deviation (variation) of the spherical aberration caused by the manufacturing errors of optical element of the converging optical system such as a lens (for example, errors of a form of the surface or errors of thickness on an optical axis) aberration caused by, if a spherical aberration deviation correcting element can correct the spherical aberration deviation of fourth example manufacturing precision does not need to be too severe, and lens productivity can be enhanced.

[0087] Incidentally, when temperature rises, spherical aberration is generated on an information recording plane in the case of a refractive lens, in general, while, when temperature falls, undercorrected spherical aberration is generated. (However, when a objective lens having two lenses is used, undercorrected spherical aberration is sometimes generated when temperature rises.) When humidity rises, undercorrected spherical aberration is generated on an information recording plane in the case of a refractive lens, in general, while, when humidity falls, overcorrected spherical aberration is generated. When a wavelength of a light source turns out to be long, overcorrected spherical aberration is generated on an information recording plane in the case of a refractive lens, in general, while, when a wavelength of a light source turns out to be short, undercorrected spherical aberration is generated. Further, when a thickness of a transparent substrate of an optical information recording medium is increased, overcorrected spherical aberration is generated on an information recording plane in the case of a refractive lens, in general, while, when a thickness of a transparent substrate is decreased, undercorrected spherical aberration is generated.

[0088] Further, it is preferable that spherical aberration deviation correcting element can correct the spherical aberration from 0.07 lambda rms up to 0.2 lambda rms to not larger than 0.07 lambda rms. Further preferably, the spherical aberration from 0.07 lambda rms up to 0.5 lambda rms can be corrected to not larger than 0.07 lambda rms.

[0089] The spherical aberration deviation (variation) correcting element may have a movable element movable in the optical axis direction, or may be composed of only a fixed element. Further, the spherical aberration deviation correcting element may be a combination of the movable element and the fixed element.

[0090] A mode in which the spherical aberration deviation (variation) correcting element has the

movable element will be described below. In the case where it has the movable element, when the movable element moves in the optical axis direction, the movable element can change the slope angle of the marginal ray of an exit light flux by moving in an optical axis direction, and the deviation (variation) of the spherical aberration is corrected. In this connection, the movable element is preferably a lens or a lens group. More preferably, the movable element has a plastic lens. When the spherical averration deviation correcting element has the fixed element together with the movable element, the fixed element may also have a plastic lens. Further, preferably, the movable element has an aspheric lens having an aspheric surface on at least one surface. It may be a lens which has two aspheric surfaces. When it has the fixed element together with the movable element, the fixed element may also have an aspheric lens. Further, the optical pick-up apparatus preferably has a moving device to move the movable element in the direction of an optical axis. For example, the voice coil actuator or the piezoelectric actuator can be used as the moving device.

[0091] The first example having the movable element is an example in which the converging optical system has coupling lens, and at least one lens group in the lens group constructing the coupling lens is a movable element of the spherical aberration deviation (variation) correcting element. The coupling lens is composed of one or plural lens groups, and one lens group is composed of one or plural lenses. Incidentally, with regard to a "lens group" in the invention, one lens or a set of plural lenses each having the same movement is regarded as one lens group, in the case of lenses moving in the direction of an optical axis, and one lens or a set of plural lenses which are in contact with adjacent lenses is regarded as one lens group, in the case of lenses which do not move in the direction of an optical axis. Therefore, when two lenses which do not move in the direction of an optical axis are present to be away from each other, these lenses are regarded as different lens groups.

[0092] The one example of the frist example will be shown. The converging optical system has the coupling lens having at least 2 lens groups, and at least one lens group among at least 2 lens groups constituting the coupling lens is a movable element of a spherical aberration deviation correcting element. Incidentally, all lens groups constituting the coupling lens may move in the direction of an optical axis, or, one or plural lens groups which do not move in the direction of an optical axis may be used as a fixed element. The example is shown in Fig. 40.

[0093] In this connection, in the lenses shown in Fig. 40, the coupling lens is composed of 2 elements (lenses) in 2 groups. The positive lens is the movable element of the spherical aberration deviation correcting element. Of course, in the example 1-1, the one lens group of coupling lens may be composed of one lens, or a plurality of lenses. Further, in one lens group, a plurality of lenses may be cemented or not cemented. Further, in the example 1-1, the coupling lens composed of 2 lens groups may be composed of the positive lens group and the negative lens group, or may be composed of the positive lens group and the positive lens group. In the case of the coupling lens composed of the positive lens group and negative lens group, the positive lens group may be the movable element, or the negative lens group may be the movable element. In this connection, it is preferable that the coupling lens has a plastic lens. Particularly, the movable element preferably has a plastic lens. Further, the coupling lens has preferably the aspheric lens. Particularly, the movable element preferably has the aspheric lens.

[0094] In the example 1-1, when the coupling lens is composed of two lens groups, it is preferable to move a movable element so that a distance between two groups of the coupling lens may be reduced, when spherical aberration varies in the overcorrected deviation on the information recording plane, and it is preferable to move a movable element so that a distance between two groups of the coupling lens may be extended when spherical aberration varies in the undercorrected deviation on the information recording plane.

[0095] Next, the another example of the first example (example 1-2) will be shown. Also in this mode, the coupling lens is the movable element of the spherical aberration deviation correcting element. The coupling lens in the converging optical system is composed of only one lens group, and the one lens group of coupling lens is the movable element of the spherical aberration deviation correcting element. That example is shown in Fig. 62.

[0096] In this connection, in the coupling lens shown in Fig. 62, the coupling lens is composed of one element in one group, and the element is a positive lens, and the positive lens is the movable element of the spherical aberration deviation correcting element. Of course, in the example 1-2, one lens group of the coupling lens may be composed of one lens, or may be composed of a plurality of lenses. Further, in the one lens group, a plurality of lenses may be cemented, or not cemented. In this connection, it is preferable that the coupling lens has a plastic lens. Further, it is preferable that the coupling lens has an aspheric lens.

[0097] In the example 1-2, it is preferable that the following conditional expression is satisfied.
0.05 </= ¦m¦ </= 0.5 (m < 0)
m: the magnification of the combined system of the objective lens and the coupling lens.

[0098] It is more preferable that the following conditional expression is satisfied.
0.1 </= ¦m¦ </= 0.5 (m < 0)

[0099] In the example 1-2, when spherical aberration varies in the overcorrected direction on the information recording plane, it is preferable that the coupling lens is moved so that a distance between the coupling lens and the objective lens may be extended, while when spherical aberration varies in the under corrected direction on the information recording plane, it is preferable that the coupling lens is moved so that a distance between the coupling lens and the objective lens may be reduced.

[0100] An example of an embodiment which is more preferable in the first example having therein a movable element will be shown below. A wavelength of a light source is not more than 500 nm, at least one lens in the coupling lens has a diffractive surface having a ring-shaped diffractive structure, the lens having a diffractive surface is a plastic lens, and the movable element is a plastic lens and an objective lens is a plastic lens.

[0101] Next, the second example having the movable element will be shown. The second example is an example in which the converging optical system has a coupling lens, and has the positive lens group having at least one positive lens and the negative lens group having at least one negative lens, between the coupling lens and the objective lens, and at least one of the positive lens group and the negative lens group is the movable element of the spherical aberration deviation correcting element. Further, its one example is shown in Fig. 1.

[0102] In the second example, the positive lens group and the negative lens group may be composed of respectively one lens, or may be composed of a plurality of lenses. Further, in respective lens groups, a plurality of lenses may be cemented or not cemented. In this connection, it is preferable that the positive lens group, or the negative lens group has the plastic lens. More preferably, the movable lens groups have the plastic lens. Further, it is preferable that the positive lens group or the negative lens group has the aspheric lens. More preferably, the movable lens groups have the aspheric lens.

[0103] Further, in the second example, the converging optical system may have a beam expander, and the beam expander may also have the positive lens group and the negative lens group. Of course, in this case also, at least one of the positive lens group and the negative lens group is the movable element of the spherical aberration deviation correcting element. It is preferable that the beam expander has a moving device to move the movable element. For example, the voice coil actuator or the piezoelectric actuator can be used as the moving device.

[0104] In this connection, in the optical system shown in Fig. 1, the coupling lens having positive refractive power is composed of one element in one group, and the one element is a positive lens and the beam expander is provided between the coupling lens and the objective lens, and the beam expander is composed of one negative lens and one positive lens, and the negative lens is the movable element of the spherical aberration deviation correcting element.

[0105] In the second example, it is preferable that the following conditional expression is satisfied.

| fP/fN | >/= 1.1

fP: the focal distance of the positive lens group (when the positive lens group has the diffractive surface, fP is the total focal distance in which the refractive power and the diffractive power are combined together)
fN: the focal distance of the negative lens group (when the negative lens group has the diffractive surface, fN is the total focal distance in which the refractive power and the diffractive power are combined together).

[0106] More preferably,
| fP/fN | >/= 1.2.

[0107] Further preferably,
2.0 >/= | fP/fN | >/= 1.2.

[0108] Further more preferably,
2.0 >/= | fP/fN | >/= 1.3.

[0109] In the example 2, in which a beam expander is composed of two lens groups including a positive lens group and a negative lens group, when spherical aberration varies in the overcorrected deviation on the information recording plane, it is preferable that the movable element is moved so that a distance between the two lens groups of the beam expander is reduced, while, when spherical aberration varies in the undercorrected deviation on the information recording plane, it is preferable that the movable element is moved so that a distance between the two lens groups of the beam expander may be extended.

[0110] Incidentally, a preferable embodiment in the second example having therein a movable element will be shown below. A wavelength of a light source is not more than 500 nm, at least one lens among positive lens group or a negative lens group has a diffractive surface having a ring-shaped diffractive structure, a lens having a diffractive surface is a plastic lens, and the movable element is a plastic lens and an objective lens is a plastic lens.

[0111] Next, there will be described an occasion wherein a spherical aberration deviation correcting element has no movable element but has only a fixed element which does not move in the direction of an optical axis. It is preferable that the fixed element is represented by an element whose refractive index distribution in the direction perpendicular to an optical axis is variable. For example, there is given a liquid crystal element. An example of a preferable fixed element whose refractive index distribution is variable will be shown below.

[0112] Fig. 63 shows the example 1. Between the objective lens and the collimator lens, there is arranged refractive index distribution variable element 21 whose refractive index distribution is variable, as shown in Fig. 63.

[0113] As refractive index distribution variable element 21, it is possible to use an element wherein electrode layers a, b and c which are electrically connected each other and are transparent optically, for example, and refractive index distribution variable layers d and e which are insulated electrically from the electrode layers a, b and c and change in terms of refractive index distribution in accordance with impressed voltage are laminated alternatively, and optically transparent electrode layers a, b and c are divided into plural areas.

[0114] In Fig. 63, when deviation of spherical aberration is detected, voltage is impressed on electrode layers a, b and c by driving means 22 for refractive index distribution variable element 21 so that refractive index of refractive index distribution variable layers d and e may be changed depending on locations, and a phase of light emerging from refractive index distribution variable

element 21 is controlled so that deviation of spherical aberration may be zero.

[0115] Fig. 64 shows an example of another refractive index distribution variable element. Refractive index distribution variable element 23 in Fig. 64 is equipped with liquid crystal element 23a on which liquid crystal molecules are arranged in order in the arbitrary X direction on a plane perpendicular to an optical axis and with liquid crystal element 23b on which liquid crystal molecules are arranged in order in the Y direction perpendicular to the X direction on a plane perpendicular to an optical axis. Liquid crystal element 23a and liquid crystal element 23b are laminated alternatively with an inbetween of glass base board 23c, and 1/2 wavelength plate 23d is arranged between inner glass substrate 23c.

[0116] In Fig. 64, when deviation of spherical aberration is detected, deviation of spherical aberration is corrected by impressing voltage on each of liquid crystal element 23a and liquid crystal element 23b both of refractive index distribution variable element 23 with driving means 22, and thereby, by controlling component in X direction and component in Y direction of light emerging from refractive index distribution variable element 23 independently.

[0117] Refractive index distribution variable element 21 and refractive index distribution variable element 23 shown respectively in Fig. 63 and Fig. 64 make it possible to constitute a converging optical system which has no movable element and has structure that is mechanically simple.

[0118] Further, it is preferable that the converging optical system has the axial chromatic aberration correcting element to correct the axial chromatic aberration of the converging optical system. Particularly, in the case where the converging optical system has the plastic lens, particularly the objective lens is the plastic lens, a problem of the axial chromatic aberration becomes conspicuous, and it is preferable that converging optical system has the axial chromatic aberration correcting element. Further, in the case that the wavelength of the light source is 500 nm or less, it is preferable to comprise the axial chromatic aberration correcting element, since the axial chromatic aberration becomes larger. In this connection, the axial chromatic aberration correcting element and the spherical aberration deviation correcting element may be composed of the same optical elements or members, or may be composed of different optical elements or members. One of the axial chromatic aberration correcting element and the spherical aberration deviation correcting element may be incorporated in the other one. Further, a part of the spherical aberration deviation correcting element and a part of the axial chromatic aberration correcting element may be the same optical element. Further, the axial chromatic aberration correcting element may be composed of one optical element, or may have more than 2 optical elements.

[0119] It is preferable that in case that the axial chromatic aberration correcting element comprises at least one positive lens group (including only one lens or plural lenses) having one positive lens and at least one negative lens group (including only one lens or plural lenses) having one negative lens, and the following condition is satisfied.
nu dP > nu dN

nu dP: an average of Abbe's numbers of d lines of all the positive lenses of the conversing optical system
nu dN: an average of Abbe's numbers of d lines of all the negative lenses of the conversing optical system

[0120] Further preferably, the following condition is satisfied.
nu dP > 55

nu dN < 35

[0121] Further, in the case of the above second example in which the spherical aberration deviation correcting element has the movable element, as the axial chromatic aberration correcting element, it is preferable that the following conditional expression is satisfied.

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DELTA d . ¦ fP/fN ¦/ DELTA nu d </= 0.05

DELTA d: the movement amount (mm) of the movable element when the information is recorded or reproduced for one information recording plane of one arbitrary optical information recording medium for which the information can be recorded or reproduced,
fP: the focal length (mm) of the positive lens group (in this connection, when the diffractive surface is provided on the positive lens group, the total focal length in which the refractive power and the diffractive power are combined),
fN: the focal length (mm) of the negative lens group (in this connection, when the diffractive surface is provided on the negative lens group, the total focal length in which the refractive power and the diffractive power are combined), DELTA nu d: the difference between the maximum value of Abbe's number of the positive lens and the minimum value of Abbe's number of the negative lens, in the positive lens group and the negative lens group.

[0122] Incidentally, it is preferable that DELTA d is defined as follows.

[0123] DELTA d: The movement amount (mm) of a movable element necessary for correcting deviation of spherical aberration caused by temperature rise of 30 DEG C from standard temperature (preferably, temperature within a range of 15 - 35 DEG C) to 0.05 lambda rms or less

[0124] Further, in the case of the above second example in which the spherical aberration deviation correcting element has the movable element, as the axial chromatic aberration correcting element, it is preferable that the following conditional expression is satisfied.
DELTA d . ¦ fP/fN ¦</= 0.5

[0125] Further, it is preferable that the axial chromatic aberration correcting element has the diffractive surface having the ring-shaped diffractive structure. It is preferable because the correction can be more intensely conducted, as compared to a case in which the axial chromatic aberration is corrected by the regulation of Abbe's number. The diffractive surface may be provided on the objective lens, or coupling lens, or on the other lens, or on the optical element other than lenses. Of course, diffractive surface may also be provided on the optical element comprised in the spherical aberration deviation correcting element. Further, a diffractive surface may be provided on one side or both sides of the lens. The optical element provided with the diffractive surface becomes the axial chromatic aberration correcting element.

[0126] Further, when axial chromatic aberration correcting element has a positive lens group having at least one positive lens (having only one lens or plural lenses), a negative lens group having at least one negative lens (having only one lens or plural lenses) and further, at least one diffractive surface, it is preferable that Abbe's number of d line for each of all positive lenses of the converging optical system is not more than 70, and Abbe's number of d line for each of all negative lenses of the converging optical system is not less than 40.

[0127] When providing a axial chromatic aberration correcting element having a diffractive surface, it is preferable that the following conditional expression is satisfied, when "a" represents the axial chromatic aberration caused by reflective index dispersion of a converging optical system (induding objective lens and other optical elements) when a wavelength of a light source varies (preferably, varies by - 10 nm to +10 nm),
and "b" represents the sum total of the axial chromatic aberrations caused by both refractive index dispersion of the converging optical system and a diffractive surface.
¦a¦ > ¦b¦

[0128] Further, it is preferable that the diffractive surface suppresses axial chromatic aberration caused by an objective lens when a wavelength of a light source varies. In particular, it is preferable that axial chromatic aberration is suppressed when a wavelength slightly varies by -10

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nm to +10 nm. Further, when a wavelength of a light source varies, it is preferable that axial chromatic aberration caused by the diffractive surface and axial chromatic aberration caused by refractive index dispersion of a converging optical system offset each other for the most part (preferably, perfectly). Further, when the wavelength of a light source increases, it is preferable that the diffractive surface has wavelength characteristics which make the back focus to be short. Further, it is preferable that the diffractive surface corrects spherical aberration so that spherical aberration caused by refractive index dispersion of a converging optical system when a wavelength of a light source varies may be made to approach the spherical aberration of the converging optical system in the case of the standard wavelength. To be more concrete, it is preferable that undercorrected spherical aberration caused by the diffractive surface when a wavelength of a light source increases, corrects overcorrected spherical aberration caused by refractive index dispersion of the converging optical system. It is further preferable that spherical aberration caused by the diffractive surface when a wavelength of a light source varies and spherical aberration caused by the refractive index dispersion of a converging optical system offset each other for the most part (preferably, perfectly). When the wavelength of a light source increases, it is preferable that the diffractive surface has spherical aberration characteristics which make spherical aberration to be undercorrected. Further, it is preferable that the diffractive surface generates an amount of nth-ordered diffracted ray (n represents integers other than 0, +/-1) to be greater than that of anyother ordered diffracted ray.

[0129] Further, it is preferable that the axial chromatic aberration correcting element satisfies the following conditional expression.
$P2 < P1 < P3$

P1: the paraxial power of the axial chromatic aberration correcting element at the wavelength of light source,
P2: the paraxial power of the axial chromatic aberration correcting element at the wavelength which is 10 nm shorter than the wavelength of the light source,
P3: the paraxial power of the axial chromatic aberration correcting element at the wavelength which is 10 nm longer than the wavelength of the light source.

[0130] When the axial chromatic aberration correcting element has a diffractive surface, each of the paraxial powers P1, P2, P3 stated above are the total paraxial powers wherein paraxial refractive power and paraxial diffractive power are combined.

[0131] When the objective lens is composed of one lens, it is preferable that the following conditional expression is satisfied.
$1.1 \leq d1/f \leq 3$

d1: the axial lens thickness of the objective lens,
f: the focal distance of the objective lens

[0132] More preferably, $1.2 \leq d1/f \leq 2.3$, and further preferably, $1.4 \leq d1/f \leq 1.8$.

[0133] The condition mentioned above is especially appropriate in the objective lens of an optical pickup apparatus used for reproducing or recording of information for only optical information recording medium or media whose necessary numerical aperture is 0.65 or more.

[0134] Further, it is preferable that the objective lens is the plastic lens.

[0135] As the material of the optical element in the present invention, the following is listed as the preferable materials. Further, it is more preferable that the optical element, particularly the movable element comprised of the spherical aberration deviation correcting element, or the objective lens is made of the following materials. The material whose specific gravity is not larger than 2.0. The material whose saturated water absorption is not larger than 0.5 %. The

material, for the light of the wavelength of the light source, whose internal transmitance at the 3 mm thickness is not smaller than 85 %. Plastics satisfying one or more of the above conditions.

[0136] Further, the optical pick-up apparatus of the present invention may be made so that it conducts the recording and /or reproducing of the information of only one kind of optical information recording medium, or it can also conduct the recording and /or reproducing of the information of more than 2 kinds of different optical information recording media.

[0137] For example, when the optical pick-up apparatus can conduct the recording and /or reproducing of the information of 2 kinds of optical information recording media, it is preferable that the optical pick-up apparatus has the first light source to emit the first light flux of the wavelength of lambda 1 to conduct the reproducing and/or recording of the first optical information recording medium, and the second light source to emit the second light flux of the wavelength of lambda 2 (lambda 1 NOTEQUAL lambda 2) to conduct the reproducing and/or recording of the second optical information recording medium. The converging optical system converges at least a portion of the first light flux onto the information recording plane of the first optical information recording medium so that the information of the first optical information recording medium can be recorded and/or reproduced, and converges at least a portion of the second light flux onto the information recording plane of the second optical information recording medium so that the information of the second optical information recording medium can be recorded and/or reproduced.

[0138] In this connection, the different kind of optical information recording medium includes cases in which the recording density of the information is different, the necessary numerical aperture for recording and/or reproducing is different, the wavelength used for recording and/or reproducing of the information is different, the thickness of the transparent substrate is different, or the combination of these cases. As a preferable example, the combination in which lambda 1 < lambda 2, and the recording density of information of the first optical information recording medium is higher than the density of the second information recording medium, and the transparent substrate thickness of the first optical information recording medium is thinner than the transparent substrate thickness of the second optical information recording medium, and the necessary numerical aperture for recording and/or reproducing information of the first optical information recording medium is larger than the necessary numerical aperture for recording and/or reproducing information of the second optical information recording medium, is listed.

[0139] Especially, when a thickness of the first transparent substrate of the first optical information recording medium is different from a thickness of second transparent substrate of the second optical information recording medium, the spherical aberration deviation correcting element may correct variation of spherical aberration caused by a difference between a thickness of the first transparent substrate and that of the second transparent substrate.

[0140] As the structure to record and/or reproduce 2 kinds of different optical information recording media by one optical pick-up apparatus, various modes can be applied.

[0141] As the first example, a mode in which the spherical aberration deviation correcting element having the movable element of the spherical aberration deviation correcting element is used, is listed. When the movable element of the spherical aberration deviation correcting element is moved in the optical axis direction, the slop angle of the marginal ray of the incident light flux into the objective lens is changed, and the deviation of the spherical aberration generated by the difference of the transparent substrate thickness of 2 kinds of optical information recording media is corrected, and the light flux is converged onto respective information recording planes so that the information can be recorded and/or reproduced.

[0142] The second example is a mode in which the diffractive surface is used. The diffractive surface is provided on the optical element in the converging optical system, and by using the difference of the position of the focus point of the diffracted light by difference of the wavelengths of 2 light sources, the spherical aberration caused by the difference of the transparent substrate thickness of 2 kinds of the optical information recording media is corrected, and the light fluxes are converged onto respective information recording planes so that the

information can be recorded and/or reproduced. The diffractive surface may be provided on the coupling lens, or the objective lens, or may be provided also on the other optical elements.

[0143] The third example is a mode in which the optical element such as an objective lens having at least 3 divided surfaces formed concentric circularly around the optical axis is used. When the divided surface closest to the optical axis is the first divided surface, its outside divided surface is the second divided surface, and its outside surface is the third divided surface, the light flux passed through the first divided surface and the third divided surface is converged onto the information recording plane of the first optical information recording medium so that the information can be recorded and/or reproduced. On the one hand, the light flux passed through the first divided surface and the second divided surface is converged onto the information recording plane of the second optical information recording medium whose necessary predetermined numerical aperture is smaller than the first optical information recording medium, so that the information can be recorded and/or reproduced.

[0144] Incidentally, on the outside of the third divided surface, one or plural divided surfaces may be further provided.

[0145] The fourth example is an embodiment wherein an objective lens has, on its at least one surface, ring-shape stepped sections which divide an incident light flux through refraction effect into a ring-shaped light flux (in this case, 1<st>, 2<nd>, ... k-th light fluxes in the order from the optical axis side to its outside) in quantity of k ($k \geqslant 3$), spherical aberration component of wavefront aberration of the 1<st> and k-th light fluxes in the position of the best image plane made by the 1<st> and k-th light fluxes is 0.07 lambda 1 rms or less, at least two light fluxes among the 2<nd> to (k-1)-th fluxes form a position of an apparent best image plane at the location different from the position of the best image plane made by the 1<st> and k-th light fluxes, and at the position of the best image plane made by the 1<st> and k-th light fluxes, wavefront aberration of light in each of 1<st> to k-th light fluxes passing through the prescribed numerical aperture on the image side of the objective lens needed for recording and/or reproducing of information of the first optical information recording medium is almost mi lambda 1 (mi is an integer and i = 1, 2, ..., k).

[0146] Further, two or more of above four examples may be combined. In all of the above 4 examples, when the light flux of the first light source of the wavelength lambda 1 is converged onto the information recording plane of the first optical information recording medium, it is preferable that, within the predetermined numerical aperture for recording and/or reproducing information of the first optical information recording medium, the wave front aberration on the information recording plane is not larger than 0.07 lambda 1 rms, and more preferably, not larger than 0.05 lambda 1 rms. Further, when the light flux of the second light source of the wavelength lambda 2 is converged onto the information recording plane of the second optical information recording medium, it is preferable that, within the predetermined numerical aperture for recording and/or reproducing information of the second optical information recording medium, the wave front aberration on the information recording plane is not larger than 0.07 lambda 2 rms, and more preferably, not larger than 0.05 lambda 2 rms.

[0147] When predetermined numerical aperture NA1 for recording and/or reproducing information of the first optical information recording medium is greater than predetermined numerical aperture NA2 for recording and/or reproducing information of the second optical information recording medium, and when a light flux of the second light source having wavelength of lambda 2 is converged on an image recording plane of the second optical information recording medium, it is preferable that light fluxes within NA2 are converged so that wavefront aberration on the information recording plane is 0.07 lambda 2 rms or less, and light fluxes within NA1 are converged so that wavefront aberration on the information recording plane may be greater than 0.07 lambda 2 rms. It is more preferable to be not more than 0.05 lambda 2 rms within NA2 and to be not less than 0.2 lambda 2 rms within NA1.

[0148] Incidentally, when two kinds or more kinds of different optical information recording media are subjected to recording and/or reproducing by one optical pickup apparatus, and these optical information recording media include one whose necessary numerical aperture for

recording and/or reproducing information is less than 0.65, and when an objective lens is composed of one lens, it is preferable that the following conditional expression is satisfied;
0.7 </= d1/f </= 2.4
wherein, d1 represents an axial lens thickness of the objective lens, and f represents a focal length of the objective lens at lambda 1.

[0149] It is preferable that the objective lens satisfying the conditional expression stated above has at least one aspheric surface.

[0150] Further, the optical information recording medium may have a plurality of information recording planes on the one side of optical information recording medium. For example, there may be listed the structure that a transparent substrate and a information recording layer are alternately piled in a plurality of stacked layers in the order from the same light flux incident side surface. In this case, the converging optical system can converge the light flux emitted from the light source onto respective information recording planes of the optical information recording medium so that the information of the optical information recording medium can be recorded and/or reproduced.

[0151] For the structure to record and/or reproduce information of the optical information recording medium having a plurality of information recording planes, various modes can be applied. For example, a mode in which the spherical aberration deviation correcting element having the movable element is used, is listed. When the movable element of the spherical aberration deviation correcting element is moved in the optical axis direction, the slope angle of the marginal ray of the incident light flux into the objective lens is changed, and the deviation of the spherical aberration generated by the position of each information recording plane is corrected, and the light flux is converged onto respective information recording plane so that the information can be recorded and/or reproduced.

[0152] Further, in the above description, when the light flux of the wavelength lambda is converged onto each information recording plane of the optical information recording medium, it is preferable that, within a predetermined numerical aperture for recording and/or reproducing information of the optical information recording medium, the wave front aberration on the information recording plane is not larger than 0.07 lambda rms, and more preferably, not larger than 0.05 lambda rms.

[0153] Further, it is preferable that the optical pickup apparatus of the invention has a spherical aberration deviation detection means that detects deviation of spherical aberration caused in a converging optical system. Based on the results of the detection by this detection means, the deviation of spherical aberration can also be corrected by moving a movable element when the spherical aberration deviation detection means has the movable element, or by changing refractive index when the spherical aberration deviation correcting element has a means whose refractive index distribution in the direction perpendicular to an optical axis is variable.

[0154] Further, the optical information recording medium recording and/or reproducing apparatus of the present invention in order to record and/or reproduce the information of the optical information recording medium, has the optical pick-up apparatus, as described above, of the present invention. Preferably, it has a spindle motor or a power source.

[0155] The aspherical surface used in the present embodiment, is expressed by the following [Equation 1]. Where, X is the axis in the optical axis direction, h is the axis in the perpendicular direction to the optical axis, and the advancing direction of the light is positive, r is the paraxial radius of curvature, kappa is a conical coefficient, and A21 is the aspherical surface coefficient.
EMI177.1

[0156] The spherical surface used in the present embodiment is expressed by [Equation 2] as the optical path difference function.
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[0157] Referring to the drawings, the preferable embodiments of the present invention will be described below. Fig. 1 is an outline structural view of the optical pick-up apparatus according to the present embodiment. In Fig. 1, the first light source 11 to conduct the recording and/or reproducing for the first optical information recording medium 24, and the second light source whose wavelength is different from the first light source 11 to conduct the recording and/or reproducing for the second optical information recording medium 23 are provided, and coupling lenses 21 and 22 to convert the divergent angles of the divergent light fluxes emitted from respective light sources, a beam splitter 62 which is an optical path composition means for making the light fluxes emitted from respective light sources advance in almost the same direction, an objective lens 3 to light-converge the light flux from the beam splitter 62 onto the information recording plane 5 of the optical information recording medium, and light detectors 41 and 42 to light-receive the reflected light from the optical information recording medium, are provided. In the drawing, numeral 8 is a diaphragm, numeral 9 is a cylindrical lens, numerals 71 and 72 are 1/4 wavelength plates, numeral 15 is a coupling lens to reduce the divergent angle of the divergent light flux from the light source 11, numeral 16 is a concave lens, and numeral 17 is a hologram to separate the reflected light flux.

[0158] Further, in the present embodiment, as a means for correcting the variation of the spherical aberration of the objective lens 3 and a divergent angle changing means, a negative lens 5 and a positive lens 4 which are arranged in order from the light source side and an actuator 7 are provided, (hereinafter, these are also called a spherical aberration correction means, and a divergent angle changing means). The actuator 7 functions as a transfer apparatus to change the slope angle of the marginal ray of the light flux by moving the negative lens 5 as an optical element in the optical axis direction. Further, relating to the present embodiment, in examples 1 to 14 showing a specific portion of the optical system, an example of so-called beam expander structured by the transferable negative lens 5 and the positive lens 4, is sometimes expressed as the spherical aberration correction means. In this connection, numeral 6 is an actuator to dive the objective lens 3 in the optical axis direction for focusing. It is defined that the first light source 11 can emit the laser light of wavelength lambda 1 = 405 nm, and the second light source 12 can emit the laser light of wavelength lambda 2 = 655 nm.

[0159] In the examples being described below, in examples 1, 2, 11, 12, the diffractive surface is provided on the objective lens 3 and the axial chromatic aberration is corrected, and in examples 3 to 5, a specific material is used for the negative lens 5 and the positive lens 4 and the axial chromatic aberration is corrected, and in examples 6 to 8, 13 and 14, the diffractive surface is provided on at least one of the negative lens 5 and the positive lens 4, and the axial chromatic aberration of the objective lens 3 is corrected, and in examples 9 and 10, the axial chromatic aberration of the objective lens 3 is corrected by the synergetic effect of the specific material of the negative lens 5 and the positive lens 4 and the diffractive surface provided on the positive lens 4. Further, examples 4, 5 and 12 are examples to conduct the recording or reproducing of the information by using the same optical system for the different optical information recording media. In this connection, in the following examples of the objective lens 3, it is formed by using the plastic material whose saturated water absorption is not larger than 0.01 %, and whose internal transmitance by the light flux of the light source wavelength 400 nm is 90.5 %, and whose permeability by the light flux of the light source wavelength 700 nm is 92 %. Further, in the following example, in the example in which only the first light source 11 in the present embodiment shown in Fig. 1 is used, although a drawing of the specific embodiment is neglected, generally, in the pick-up apparatus of Fig. 1, for example, a mode in which the second light source 12, coupling lens 22, beam splitter 62, light detector 42, 1/4 wavelength plate 72 and hologram 17 are removed, can be applied. Each of examples will be described below.

[Example 1]

[0160] The data for the optical system composed of the negative lens 5, positive lens 4, and objective lens 3 in the example 1 is shown in Table 1. In this connection, in the data shown hereinafter, the powers of 10 (for example, 2.5 x 10<-3>) is expressed by using E (for example,

Optical pick-up device

Claims of corresponding document: **EP1154417**

1. An optical pickup apparatus for conducting recording and/or reproducing information of an optical information recording medium, comprising:

a light source;
a converging optical system to converge light flux emitted from the light source on an information recording plane of the optical information recording medium so as to conduct reproducing and/or recording information of the optical information recording medium, the converging optical system having an objective lens; and
a photo-detector to receive reflected light flux from the information recording plane;
wherein the converging optical system comprises at least a plastic lens and a spherical aberration deviation correcting element to correct deviation of a spherical aberration of the converging optical system and a numerical aperture of the objective lens at an image-side is 0.65 or more.

2. The optical pickup apparatus of claim 1, wherein the spherical aberration deviation correcting element comprises a movable element movable in a direction of an optical axis.

3. The optical pickup apparatus of claim 2, wherein the converging optical system comprises a coupling lens including at least a lens group working as the movable element of the spherical aberration deviation correcting element.

4. The optical pickup apparatus of claim 3, wherein the light flux emitted from the light source has a wavelength of 500 nm or less, the coupling lens has at least a diffractive surface having a ring-shaped diffractive structure, the lens having the diffractive surface is a plastic lens, the movable lens is a plastic lens and the objective lens is a plastic lens.

5. The optical pickup apparatus of claim 3, wherein the converging optical system comprises the coupling lens groups having at least two lens groups and at least one of the two lens groups works as the movable element of the spherical aberration deviation correcting element.

6. The optical pickup apparatus of claim 3, wherein the converging optical system comprises the coupling lens consisting of one lens group and the lens group works as the movable element of the spherical aberration deviation correcting element.

7. The optical pickup apparatus of claim 6, wherein the following formula is satisfied:
$0.05 \leqslant |m| \leqslant 0.5$ ($m < 0$)
where m represents a magnification of a combined optical system of the objective lens and the coupling lens.

8. The optical pickup apparatus of claim 2, wherein the converging optical system comprises a coupling lens and the converging optical system further comprises a positive lens group having at least a positive lens and a negative lens group having at least a negative lens between the coupling lens and the objective lens, and
wherein at least one of the positive lens group and the negative lens group works as the movable element of the spherical aberration deviation correcting element.

9. The optical pickup apparatus of claim 8, wherein the converging optical system comprises a beam expander having the positive lens group and the negative lens group and at least one of the positive lens group and the negative lens group is the movable element of the spherical aberration deviation correcting element.

10. The optical pickup apparatus of claim 9, wherein the light flux emitted from the light source has a wavelength of 500 nm or less, at least one of the positive lens group and the negative lens

group comprises at least a diffractive surface having a ring-shaped diffractive structure, the lens having the diffractive surface is a plastic lens, the movable element is a plastic lens and the objective lens is the plastic lens.

11. The optical pickup apparatus of claim 8, wherein the following formula is satisfied:
$|fP/fN| \geq 1.1$
where fP is a focal length (mm) of the positive lens group (where, when the diffractive surface is provided to the positive lens group, fP is the total focal length in which the refractive power and diffractive power are combined) ; and fN is a focal length (mm) of the negative lens group (where, when the diffractive surface is provided to the negative lens group, fN is the total focal length in which the refractive power and diffractive power are combined).

12. The optical pickup apparatus of claim 2, wherein the movable element is a plastic lens.

13. The optical pickup apparatus of claim 2, wherein the movable element is an aspherical lens having at least an aspherical surface.

14. The optical pickup apparatus of claim 1, wherein the spherical aberration deviation correcting element is a stationary element which does not move in a direction of an optical axis.

15. The optical pickup apparatus of claim 14, wherein a refractive index distribution of the stationary element along the direction perpendicular to the optical axis is changeable.

16. The optical pickup apparatus of claim 1, wherein the converging optical system comprises an axial chromatic aberration correcting element to correct an axial chromatic aberration of the converging optical system.

17. The optical pickup apparatus of claim 16, wherein the axial chromatic aberration correcting element comprises a positive lens group having at least a positive lens and a negative lens group having at least a negative lens, and the following formula is satisfied:
$\nu dP > \nu dN$
where νdP is an average of Abbe's numbers of d-lines of all positive lenses in the converging optical system, and
νdN is an average of Abbe's numbers of d-lines of the all negative lenses in the converging optical system.

18. The optical pickup apparatus of claim 17, wherein the following formula is satisfied:
$\nu dP > 55$

$35 > \nu dN$

19. The optical pickup apparatus of claim 16, wherein the axial chromatic aberration correcting element comprises a diffractive surface having a ring-shaped diffractive structure.

20. The optical pickup apparatus of claim 19, wherein the following formula is satisfied:
$|a| > |b|$
where "a" is an axial chromatic aberration caused by refractive index dispersion of the converging optical system as the wavelength of the light source fluctuates, and "b" is the total of the axial chromatic aberration caused by the refractive index dispersion of the converging optical system and by the diffractive surface as the wavelength of the light source fluctuates.

21. The optical pickup apparatus of claim 19, wherein the under-corrected spherical aberration caused by the diffractive surface as the wavelength of the light source increases corrects the over-corrected spherical aberration caused by the refractive index dispersion of the converging optical system as the wavelength of the light source increase.

22. The optical pickup apparatus of claim 19, wherein the diffractive surface makes a diffracted light amount of n-th ordered diffracted ray (n is an integer except 0, +/- 1) larger than a diffracted

light amount of any other ordered diffracted ray.

23. The optical pickup apparatus of claim 16, wherein the axial aberration correcting element satisfies the following formula:

$P2 < P1 < P3$

where P1 is a paraxial power of the axial chromatic aberration correcting element at the wavelength of the light source, P2 is a paraxial power of the axial chromatic aberration correcting element at the wavelength shorter by 10 nm than the wavelength of the light source, and P3 is a paraxial power of the axial chromatic aberration correcting element at the wavelength longer by 10 nm than the wavelength of the light source,

(Where, when the axial chromatic aberration correcting element comprises a diffractive surface, each of the paraxial powers P1, P2 and P3 is a total paraxial power in which a paraxial refractive power and a paraxial diffractive power are combined).

24. The optical pickup apparatus of claim 1, wherein the objective lens comprises a single lens having an aspherical surface on at least one surface thereof.

25. The optical pickup apparatus of claim 24, wherein the objective lens satisfies the following conditional formula:

1.1 </= d1/f </= 3.0

where d1 is axial lens thickness, and

f is a focal length of the objective lens (where, when the objective lens comprises a diffractive surface having a ring-shaped diffractive structure, f is the total focal length in which a paraxial refractive power and a paraxial diffractive power are combined).

26. The optical pickup apparatus of claim 24, wherein the objective lens is a plastic lens.

27. The optical pickup apparatus of claim 1, wherein the optical pickup apparatus conducts reproducing and/or recording information of at least two kinds of optical information recording media, the light source is a first light source to emit a first light flux having a wavelength lambda 1 in order to conduct reproducing and/or recording information of a first information recording medium having a first transparent substrate, the optical pickup apparatus further comprises a second light source to emit a second light flux having a wavelength lambda 2 different from the wavelength lambda 1 in order to conduct reproducing and/or recording information of a second information recording medium having a second transparent substrate having a thickness different from that of the first transparent substrate; and the converging optical system converges at least a part of the first light flux on an information recording plane of the first optical information recording medium so as to conduct recording and/or reproducing information of the first optical information recording medium and converges at least a part of the second light flux onto an information recording plane of the second optical information recording medium so as to conduct recording and/or reproducing information of the second optical information recording medium.

28. The optical pickup apparatus of claim 27, wherein the spherical aberration deviation correcting element corrects deviation of the spherical aberration due to a thickness difference between the first transparent substrate and the second transparent substrate.

29. The optical pickup apparatus of claim 27, wherein the objective consists of a single lens having at least one aspherical surface and satisfies the following formula:

0.7 </= d1/f </= 2.4

where d1 is an axial lens thickness of the objective lens and f is a focal length of the objective lens at a wavelength lambda 1 (where, when the objective lens comprises a diffractive surface having a ring-shaped diffractive structure, f is the total focal length in which a paraxial refractive power and a paraxial diffractive power are combined).

30. The optical pickup apparatus of claim 27, wherein the objective lens has at least a diffractive surface having a ring-shaped diffractive structure and the objective lens converges at least a part of the first light flux on an information recording plane of the first optical information recording medium within a predetermined numerical aperture of the objective lens at an image side necessary for conducting recording and/or reproducing information of the first optical

information recording medium on a condition that a wavefront aberration is 0.07 lambda 1 rms or less and converges at least a part of the second light flux on an information recording plane of the second optical information recording medium within a predetermined numerical aperture of the objective lens at an image side necessary for conducting recording and/or reproducing information of the second optical information recording medium on a condition that a wavefront aberration is 0.07 lambda 2 rms or less.

31. The optical pickup apparatus of claim 27, wherein the objective lens comprises a ring-shaped stepped section to divide an incident light flux into k pieces of ring-shaped light flux by a refracting action where $k > 3$ and the light flux is named the first, the second, - - the k-th light flux from the optical axis to the outside, a spherical aberration component of the wavefront aberration of the first and the k-th light flux at a best image plane position formed by the first and the k-th light flux is 0.07 lambda 1 rms or less, at least two pieces of light flux among the second to (k-1)th light flux form an apparent best image plane position at a different position from the best image plane position formed by the first and k-th light flux, and the wavefront aberration of rays of each of in the first to k-th light flux passing within a predetermined numerical aperture of the objective lens at an image side necessary for conducting recording and/or reproducing information of the first optical information recording medium at the best image plane position formed by the first and k-th light flux is almost mi lambda 1, where mi is an integer, and i =1, 2, ---k.

32. The optical pickup apparatus of claim 29, wherein the objective lens is a plastic lens.

33. The optical pickup apparatus of claim 1, wherein the optical information recording medium comprises a plurality of information recording planes on one side of the optical information recording medium and converging optical system converges the light flux emitted from the light source onto each of the plurality of information recording planes of the optical information recording medium so as to conduct reproducing and/or recording information of the optical information recording medium.

34. The optical pickup apparatus of claim 33, wherein the spherical aberration deviation correcting element corrects deviation of the spherical aberration due to a difference in the thickness between a light flux incident surface of the optical information recording medium and each of the plurality of information recording planes of the optical information recording medium.

35. The optical pickup apparatus of claim 1, wherein the deviation of the spherical aberration of the converging optical system is deviation of the spherical aberration due to change in temperature and/or humidity.

36. The optical pickup apparatus of claim 1, wherein the deviation of the spherical aberration of the converging optical system is deviation of the spherical aberration due to deviation in the wavelength of the light source and/or the manufacturing errors in the wavelength of the light source.

37. The optical pickup apparatus of claim 1, wherein the deviation of the spherical aberration of the converging optical system is deviation of the spherical aberration due to deviation in thickness of a transparent substrate of the optical information recording medium.

38. The optical pickup apparatus of claim 1, wherein the wavelength of the light source is 500 nm or less.

39. The optical pickup apparatus of claim 1, wherein the spherical aberration deviation correcting element is capable of correcting the spherical aberration of A lambda rms to 0.07 lambda rms or less, where A satisfies the following formula: $0.07 < A \leqslant 0.5$.

40. An optical information recording medium recording and/or reproducing apparatus for conducting recording and/or reproducing information of an optical information recording medium, comprising:

an optical pickup apparatus comprising:

a light source;
an converging optical system to converge light flux emitted from the light source on an information recording plane of the optical information recording medium so as to conduct reproducing and/or recording information of the optical information recording medium, the converging optical system having an objective lens; and
a photo-detector to receive reflected light flux from the information recording plane;
wherein the converging optical system comprises at least a plastic lens and a spherical aberration deviation correcting element to correct deviation of a spherical aberration of the converging optical system and a numerical aperture of the objective lens at an image-side is 0.65 or more.

41. A spherical aberration deviation correcting element for use in an optical pickup apparatus for recording and/or reproducing information of the optical information recording medium, comprising:

a positive lens group having at least a positive lens; and
a negative lens group having at least a negative lens, wherein at least one of the positive lens group and the negative lens group is a movable element movable in a direction of an optical axis and the movable element can change the slope angle of the marginal ray of an exit light flux by moving in a direction of the optical axis, and
wherein each positive lens of the spherical aberration deviation correcting element has Abbe's numbers of 70 or less or each negative lens of the spherical aberration deviation correcting element has Abbe's numbers of 40 or more and the spherical aberration deviation correcting element comprise at least a diffractive surface having a ring-shaped diffractive structure.

42. The spherical aberration deviation correcting element of claim 41, wherein the following formula is satisfied:
$P2 < P1 < P3$
where P1 is a paraxial power of the spherical aberration deviation correcting element at the wavelength of the light source of the optical pickup apparatus,
P2 is a paraxial power of the spherical aberration deviation correcting element at the wavelength shorter by 10 nm than the wavelength of the light source of the optical pickup apparatus, and
P3 is a paraxial power of the spherical aberration deviation correcting element at the wavelength longer by 10 nm than the wavelength of the light source of the optical pickup apparatus,
wherein each of the paraxial powers P1, P2 and P3 is a total paraxial power in which a paraxial refractive power and a paraxial diffractive power are combined.

43. The spherical aberration deviation correcting element of claim 41, wherein the spherical aberration deviation correcting element is a beam expander.

44. The spherical aberration deviation correcting element of claim 41, wherein the spherical aberration deviation correcting element comprises at least an optical element made of plastic.

45. A spherical aberration deviation correcting unit for use in an optical pickup apparatus for recording and/or reproducing information of an optical information recording medium, comprising:

a spherical aberration deviation correcting element recited in claim 41, and
a moving device to move at least one of the positive lens group and the negative lens group in a direction of an optical axis.

46. The spherical aberration deviation correcting element unit of claim 45, wherein the following formula is satisfied:
$P2 < P1 < P3$
where P1 is a paraxial power of the spherical aberration deviation correcting element at the wavelength of the light source of the optical pickup apparatus,

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P2 is a paraxial power of the spherical aberration deviation correcting element at the wavelength shorter by 10 nm than the wavelength of the light source of the optical pickup apparatus, and P3 is a paraxial power of the spherical aberration deviation correcting element at the wavelength longer by 10 nm than the wavelength of the light source of the optical pickup apparatus, where each of the paraxial powers P1, P2 and P3 is a total paraxial power in which a paraxial refractive power and a paraxial diffractive power are combined.

47. The spherical aberration deviation correcting element unit of claim 45, wherein the spherical aberration deviation correcting element is a beam expander.

48. The spherical aberration deviation correcting element unit of claim 45, wherein the spherical aberration deviation correcting element comprises at least an optical element made of a plastic.

FIG. 1